WORLD METEOROLOGICAL ORGANIZATION

Environment and Climate Change Canada

Norwegian Meteorological Institute

Russian Federal Service for Hydrometeorology and Environmental Monitoring

ACF
Arctic Climate Forum

13th Arctic Climate Forum Consensus Statement

Summary of 2023/2024 Arctic winter-spring season and the 2024 Arctic summer Seasonal Climate Outlook

22 – 23 May 2024

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Introduction to the Arctic Climate Forum Consensus Statement

Arctic temperatures continue to rise at rates greater than the global average. Both the annual and all season's air temperatures since early 2000s in the Arctic (northward of 50°N within the ArcRCC-N domain) have been close to the highest in the time series of observations for 1900-2024 period (figure 1) though significant interannual variations occur for all Arctic Essential Climate Variables (ECV), including the surface atmosphere, sea-ice and polar ocean ECVs.

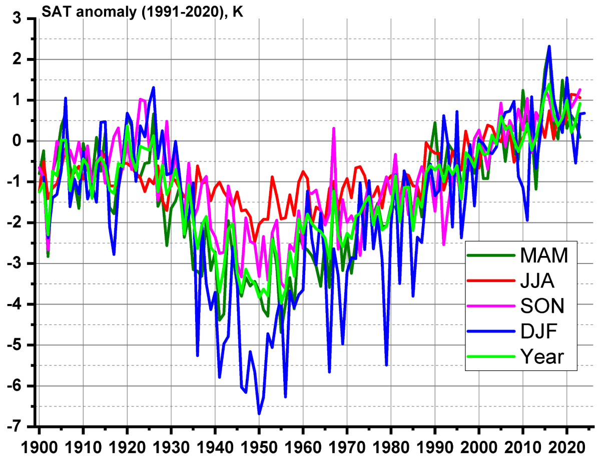


Figure 1: Annual, spring (MAM), summer (JJA), autumn (SON) and winter (DJF) average surface air temperature anomalies (ref. 1991-2020) for 1900-2023/2024 period. Graphics produced by the AARI. Data source: WMO stations within the ArcRCC-N domain (see fig.2).

The role of the ArcRCC-Network is to foster collaborative regional climate services amongst Arctic (hydro)meteorological and ice services, as to meet climate adaptation and decision-making needs among societal actors across the Arctic.

Arctic Climate Forums (ACFs) were established in 2018 and are convened by the Arctic Regional Climate Centre Network (ArcRCC-N) under the auspices of the World Meteorological Organization (WMO).

A main product of the ACFs is the Consensus Statements, which synthesize observations, historical trends, forecasts, and in doing so, include regional expertise. These statements include a review of the major climate features of the previous season and outlooks for the upcoming season for temperature, precipitation, sea-ice and several other experimental forecasts.

The elements of the Consensus Statements are presented and discussed at the Arctic Climate Forum (ACF) sessions, with both providers and users of climate information in the Arctic being held twice a year in May/June and October/November. The Consensus Statements are issued around the beginning of the summer melt and sea-ice break-up (May/June) and around the beginning of the winter sea-ice freeze-up (October/November).

This Consensus Statement is an outcome of the 13th session of the ACF held online 22-23 May 2024 coordinated by the Nordic Node of the ArcRCC-Network and hosted by the Icelandic Meteorological Office (IMO).

Highlights for decision making

Temperature: For the whole land Arctic extremely warmer conditions were observed in November 2023 and February – April 2024 with colder in January 2024 with preliminary ranks 2nd (for 1950-2023/2024 period) and 5-6th in row[1], though large regional and intraseasonal variations and changes in anomaly sign did occur. That included negative anomalies in Nordic regions varying 55-63rd in row. For the June-September 2024 period, there is a probability of 50% or more that temperatures will be above normal in most of the regions across the Arctic. The highest probabilities for an above-normal summer (60-80% or more) are in Western Nordic, Greenland, parts of Central and Eastern Canadian Arctic. Below normal temperatures are expected for Chukchi, parts of Bering and Greenland Seas with probability 40-50% and for southern parts of Barents and Kara Seas (0-40%).

Precipitation: The least amount of precipitation was for the Western Nordic, parts of W Canada & Alaska regions which is close to winter 2022/2023. More abundant precipitation was observed in the Eastern Nordic, parts of Alaska and Bering and Chukchi regions. Somewhat close to normal conditions are estimated for the Central Arctic. For the June – August 2024 period over the largest part of the Arctic region, there are no model agreements or expectancies for near normal precipitation with probabilities of 40% or less. Above normal precipitation is expected for Iceland, Greenland, Labrador Sea, parts of Canadian Archipelago and Chukchi peninsula with probability expectancies of 40-50%.

Sea-ice: Maximum Arctic (Northern Hemisphere) winter ice extent occurred 12-14 March 2024, which is close in time to climatic date, with a value of ~15.3 mln km^2 or 15-16th in row since 1979. Prominent area of residual ice in late summer led to decadal normal ice extent growth in the Eurasian Arctic. Similar to 2023 the Sea of Okhotsk and the Greenland Sea had ice extent close or higher than 46-years median and the Barents Sea-ice extent close to normal in late winter 2024. Following satellite measurements and modeling analysis, the Arctic Ocean continues to lose the volume mostly due to loss of sea-ice thickness (SIT) in the Canadian Arctic though SIT anomalies positive to 2011-2024 were also observed in parts of Eurasian and Central Arctic. For the upcoming summer 2024 season, earlier than normal freeze-up dates are forecasted for west Barents, Kara, west East Siberian, north Chukchi and Beaufort seas, south Baffin and east Hudson Bays. A near normal to late break-up is forecasted for east East Siberian Sea with late break-up forecasted for Bering Sea, south Chukchi, Labrador, south Greenland Seas, west of Hudson Bay. A below normal September ice extent is forecasted for all regions with exception of below to near normal sea-ice extent for the Barents Sea.

Ongoing Impacts of Climate Change: Increase risk of coastal flooding and thawing permafrost lead to coastal erosion and losses of community infrastructure. All marine mammals with habitat on sea ice may be more difficult to harvest. Increasing interannual and intraseasonal variability lowers predictability of weather extremes, hereby challenging planning and operational decisions among communities and stakeholders inhabiting and operating in the Arctic region.

[1] 1st rank corresponds to the highest value, 74th/75th to the lowest value within the row spanning period from 1950 to 2023/2024

Understanding the Consensus Statement

This consensus statement includes: a seasonal summary, forecast verification for temperature, precipitation, and sea-ice for the previous 2023/2024 Arctic winter-spring season (from October 2023 to April 2024) and an outlook for the upcoming 2024 Arctic summer season (from June to September 2024 period) for temperature, precipitation and sea-ice. Experimental products with outlooks for snow water equivalent and weather severity index are also included in this consensus statement. Figure 2 shows the regions, which are defined by the ArcRCC-N members on the basis of accepted regional practices to capture the different geographic features and environmental factors influencing temperature, precipitation and other Arctic ECVs. Figure 3 shows the established shipping routes and regions used for the sea-ice products.

Figure 2: ArcRCC-N regions accepted for seasonal summaries and outlooks

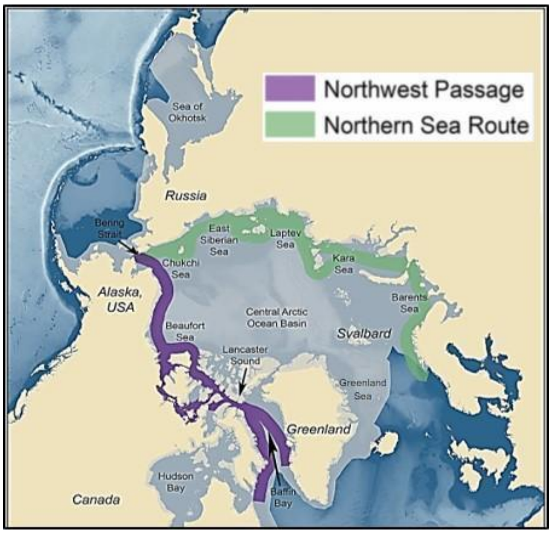


Figure 3: Sea-ice Regions. Map Source: Courtesy of the U.S. National Academy of Sciences

Seasonal summaries for temperature, precipitation, sea-ice and other Arctic ECVs are based on a synthesis of routine observations at polar stations and marine mobile platforms, sea-ice analysis from the national ice services, satellite estimates of sea-ice extent and thickness, WMO GCW SeaIceWatch and SnowWatch data, and a set of modern reanalysis products including Copernicus climate change service (ERA5, MEMS, GloFAS-ERA5) and NCEP-NCAR reanalysis. Anomalies of the parameters are given in the majority of cases for the new 3rd WMO reference period 1991-2020, which allows to efficiently underline the most recent interannual variability.

The seasonal forecasts for temperature and precipitation are based on thirteen WMO Global Producing Centers of Long-Range Forecasts (GPCs-LRF) models and consolidated by the WMO Lead Centre for Long Range Forecast Multi-Model Ensemble (LC-LRFMME). In terms of models' skill (i.e., the ability of the climate model to simulate the observed seasonal climate), a multi-model ensemble (MME) approach essentially overlays all of the individual model performances. This provides a forecast with higher confidence in the regions where different model outputs/results are consistent, versus a low confidence forecast in the regions where the models don't agree. The MME approach is a methodology well-recognized by the WMO to be providing the most reliable objective forecasts.

Sea-ice and snow water equivalent outlooks are based primarily on the Canadian Seasonal to Interannual Prediction System (CanSIPSv2.1, 20 ensemble members, 10 each from GEM5-NEMO and CanCM4i) with additional use of sea-ice forecasts from the Coupled Unified Forecast System (NOAA UFS; 5 ensemble members) and INM-CM5 climate model

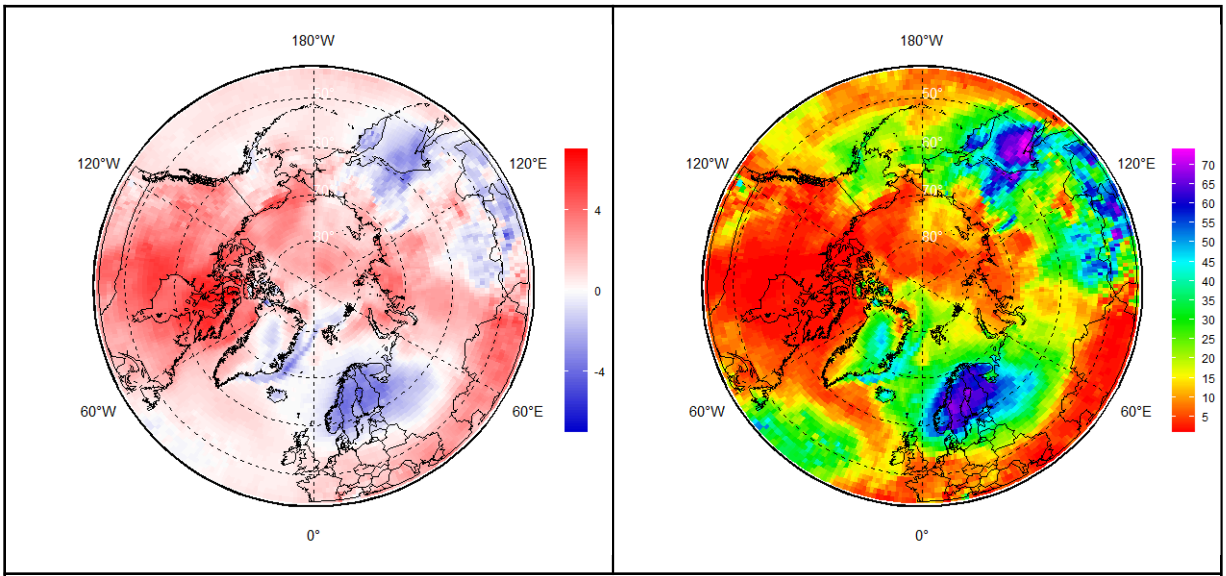
(INM RAS/Hydrometcenter of Russia, 10 ensemble members). MME for sea-ice is not yet available; the outlook is a subjective 'ensemble' of probabilistic/deterministic model forecasts. Therefore, for sea-ice the forecast confidence is a subjective assessment of hindcast model skill, ensemble spread and forecast agreement between models. When sea ice extent is at its minimum in September of each year, forecasts are available for the following peripheral seas where there is variability in the ice edge: Barents Sea, Beaufort Sea, Canadian Arctic Archipelago, Chukchi Sea, Eastern Siberian Sea, Greenland Sea, Kara Sea, and Laptev Sea. In addition to these regions, forecasts for sea ice break-up are also available for Baffin Bay, Bering Sea, East Siberian Sea, Kara Sea, Laptev Sea, Chukchi Sea, Barents Sea, Greenland Sea, Hudson Bay, and Labrador Sea.

Temperature

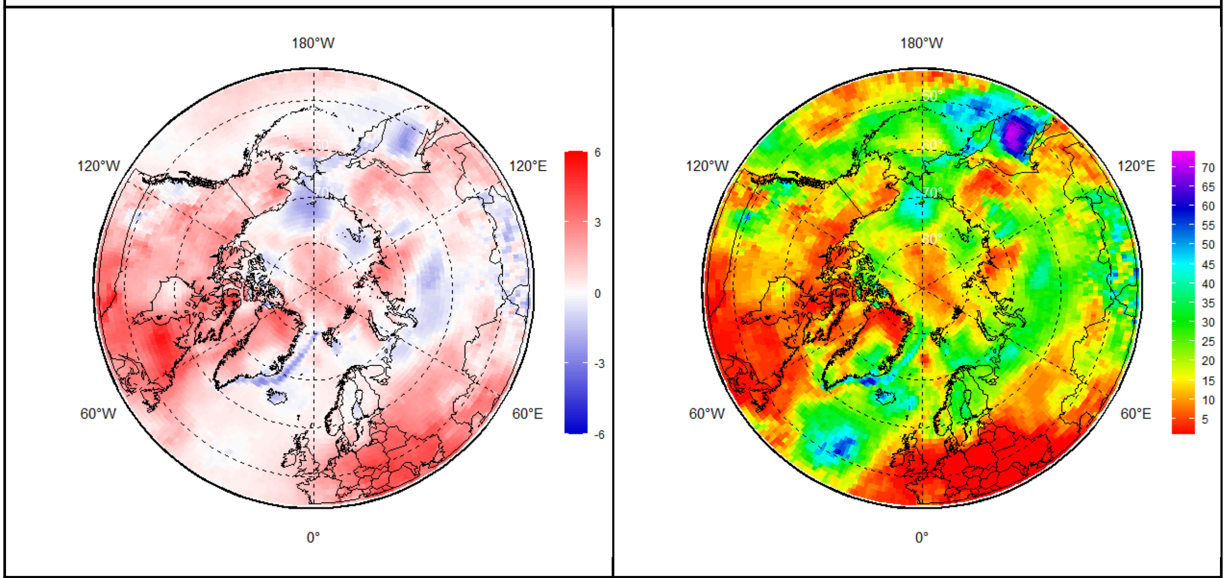
Summary for winter-spring 2023/2024

Based on direct observations at the WMO stations the start of winter 2023 (November-December) surface air temperature (SAT) showed prominent positive anomalies in Eastern Siberia (rank 3rd in row), Chukchi and Bering (rank 6th in row), Alaska (rank 7th in row) and in particular in Central and Eastern Canada (rank 1st – 3rd in row), though strong negative anomalies were observed in Western Nordic (rank 60th in row) and Eastern Nordic (rank 57-63rd in row) (anomalies are given to 3rd WMO reference period 1991-2020, all ranks are preliminary and provided to 1950-2023/2024 observation period). During mid-winter (January-February 2024) strong positive anomalies were observed over Western Siberia (ranks 7th in row) and again over Central and Eastern Canada (rank 1st in row) with negative anomalies observed over Western Nordic region (rank 62nd in row) and Eastern Siberia (rank 70th in row). Further by the end of winter in March – April 2024 strong positive anomalies were observed again over Central and Eastern Canada (rank 2nd in row) and Chukchi and Bering (rank 8th in row) with negative over Eastern Nordic (rank 55th in row). Due to lack of surface marine observations conclusions for the Central Arctic may be assessed only on reanalysis and include warmer conditions in November-January with warmer to colder during February – April 2024.

For the whole land Arctic extremely warmer conditions were observed in November 2023 and February – April 2024 with colder in January 2024 with preliminary ranks 2nd to 5-6th in row. Centennial long analysis shows that extreme negative anomalies (to 1991-2020 period) in general occurred in the mid-20th century with comparable to current decade positive anomalies occurred in 1910-1920s but that is again NOT the SAME for all of the Arctic subregions. Though positive trends from 1940s-1950s are obvious, the quantitative estimates depend on the WMO reference period chosen, density and subset of the stations chosen for the analyzed subregion, in particular for the marine Arctic.



November 2023 – January 2024 (NDF)



February – April 2024

Figure 4: Winter – spring 2023/2024 SAT anomalies, left (ref. 1991-2020), and ranks, right (ref. 1950-2023). Data source: AARI. Maps produced by the AARI. Data source: CCCS ERA5

Table 1. Surface air temperature anomalies (reference period 1991-2020) and consecutive ranks in brackets (reference period 1950-2023/2024) for October 2023 – April 2024 by the ArcRCC-N regions based on observations at polar stations

Arctic region / period	Western Nordic	Eastern Nordic	Western Siberia	Eastern Siberia	Chukchi & Bering	Alaska & Western Canada	Central & Eastern Canada	Arctic
Oct	-0.47 (41)	-1.83 (63)	2.76 (6)	3.30 (3)	1.79 (6)	0.73 (28)	1.80 (7)	0.44 (16)
Nov	-0.72 (46)	-2.70 (57)	3.72 (10)	4.09 (3)	3.70 (6)	3.50 (7)	3.75 (3)	1.56 (5)
Dec	-2.02 (60)	-2.85 (50)	1.02 (28)	0.00 (35)	-0.02 (30)	1.18 (22)	6.18 (1)	1.07 (11)
Jan	-0.31 (37)	-2.72 (54)	2.38 (14)	-0.97 (33)	1.03 (32)	-1.48 (47)	0.00 (26)	-0.98 (30)
Feb	-2.02 (62)	0.77 (25)	3.36 (7)	-0.18 (33)	-0.17 (27)	0.14 (32)	4.30 (1)	1.83 (2)

Mar	-0.72 (41)	1.93 (13)	-1.58 (41)	0.95 (19)	3.11 (8)	1.14 (30)	0.24 (20)	1.20 (6)
Apr	0.03 (27)	-1.52 (55)	-1.76 (43)	1.46 (11)	1.38 (10)	0.94 (15)	3.15 (2)	0.67 (7)
Nov-Jan	-1.00 (49)	-2.70 (61)	2.79 (8)	0.91 (17)	1.72 (10)	1.02 (25)	3.83 (1)	0.67 (13)
Feb-Apr	-1.00 (48)	-0.52 (35)	0.07 (20)	1.06 (13)	1.36 (11)	0.45 (24)	2.28 (4)	0.57 (9)

Verification of winter-spring 2023/2024 forecast

The FMA 2024 temperature forecast was verified by subjective comparison between the forecast (Figure 5, left) and ERA5 reanalysis (Figure 5, right), region by region. A reanalysis is produced using modeling and statistical techniques to fill gaps, where meteorological observations are not available.

Above normal temperatures were accurately forecasted for the Central and Eastern Canada and with lesser accuracy for the Alaska and Western Canada and Eastern Siberia regions where mostly above but also near normal temperatures occurred. Same lesser accuracy was the forecast for the Western Nordic where instead of below normal both below and near normal temperatures occurred. Forecasts were not correct in the Northeast, Western Siberia, Chukchi and Bering Sea regions, where temperatures were above normal, but rather below or close to normal. Considering all Arctic regions the subjective score is somewhat less than 40%.

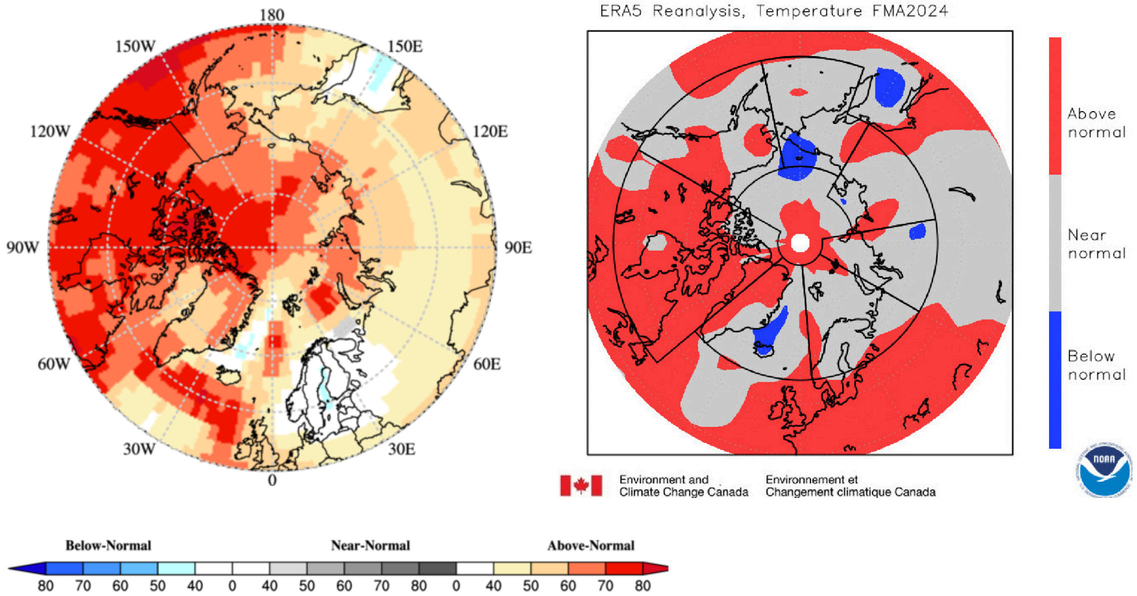


Figure 5: (Left) Multi-model ensemble (MME) probability forecast for surface air temperatures: February - April 2024. Three categories: below normal (blue), near normal (grey), above normal (red); no agreement amongst the models is shown in white. Source: www.wmolc.org. (Right): ERA5 reanalysis for air temperature for February - April 2024.

Outlook for summer 2024

For the June-July-August 2024 period, there is a probability of 50% or more that temperatures will be above normal in most of the regions across the Arctic (Figure 6: red areas; Table 2). The highest probabilities for an above-normal summer (60-80% or more) are in Western Nordic, Greenland, parts of Central and Eastern Canadian Arctic (Figure 6: dark red areas; Table 2). Below normal temperatures are expected for Chukchi Sea, Bering Strait and adjacent area of Bering Sea, western parts of Greenland Sea with probability 40-50% (Figure 6: light blue areas; Table 2). Lower probability (less than 40%) of below normal temperatures is for western part of Hudson Bay, southern parts of Barents and Kara Seas (Figure 6: white and light blue areas; Table 2).

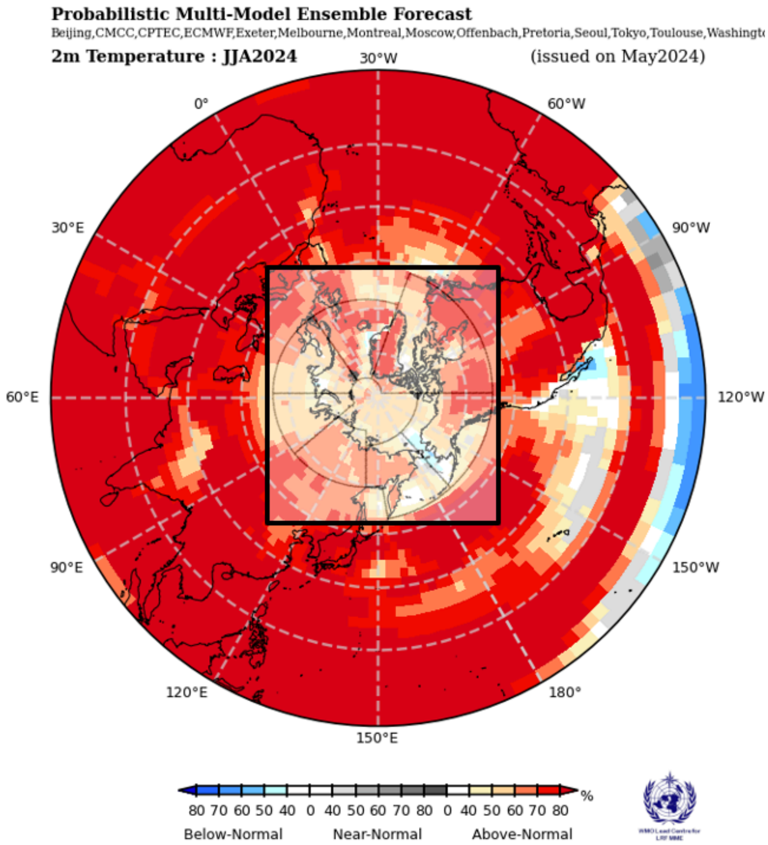


Figure 6: Multi model ensemble probability forecast for temperature for June, July, August 2024. Redder indicates higher probability for an above normal JJA, bluer color indicates higher probability for below normal summer and white, no agreement amongst the models. Source: www.wmolc.org.

Table 2:. June, July, August 2024 outlook: Arctic regional forecasts for surface air temperature

Arctic Region	**MME Temperature Forecast Agreement**	**MME Temperature Forecast**
Alaska and Western Canada	Low (eastern part), moderate to high (western part)	Above normal with exception of western part adjacent to Bering Strait and Chukchi Sea
Central and Eastern Canada	High (continental part), low (some marine parts)	Above normal for most of area, normal or below normal in parts of Hudson Bay and Labrador Sea
Western Nordic	High (Greenland, Icelandic waters, eastern part), low (parts of Greenland Sea)	Above normal (Greenland, Icelandic waters), below normal (parts of Greenland Sea)
Eastern Nordic	Moderate to low	Above normal
Western Siberia	Low to no agreement	Above normal with exception of normal for southern parts of Barents and Kara Seas
Eastern Siberia	Moderate	Above normal
Bering and Chukchi	Moderate (in continental part), low to no agreement (marine part)	Above normal with exception of below normal for Bering Strait, adjacent area of Bering Sea and Chukchi Sea/

Central Arctic	Low to moderate	Above normal

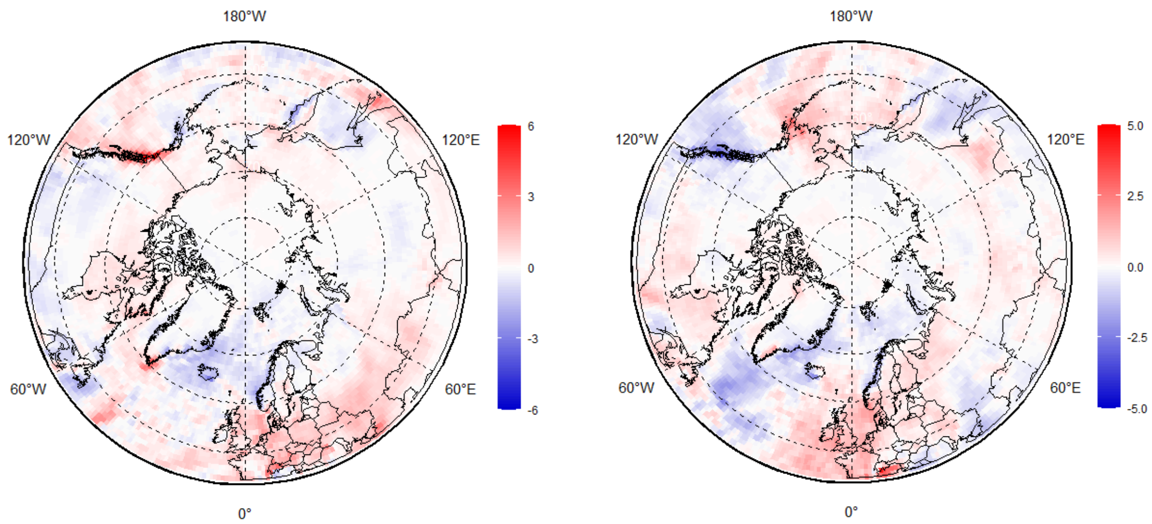
*: See non-technical regional summaries for greater detail

Precipitation

Summary for winter-spring 2023/2024

In general, during the whole season wetter (snowy) conditions occurred in parts of Canadian, Alaska, Bering & Chukchi, Siberia and Eastern Nordic regions (figure 7). Drier conditions occurred in the Nordic, parts of Canadian and Alaska regions. The least amount of precipitation was for the Western Nordic, parts of W Canada & Alaska regions which is close to winter 2022/2023 (see ArcRCC-N consensus statements for 2022 and 2023). More abundant precipitation was observed in the Eastern Nordic, parts of Alaska and Bering and Chukchi regions. Somewhat close to normal conditions are estimated for the Central Arctic.
Impacts of wetter/drier and colder/warmer weather conditions were reflected in the winter/spring 2023-2024 Arctic rivers discharge though the frozen ground restricts direct effects. Lesser discharge than normal was seen for Pechora, Ob', partly Yenisei, Mackenzie rivers through the whole season (figure 7). Yukon, partly Yenisei rivers experienced greater discharge than normal. Close to normal river discharge was estimated for Lena and further eastward Siberian rivers

Surface precipitation



River discharge

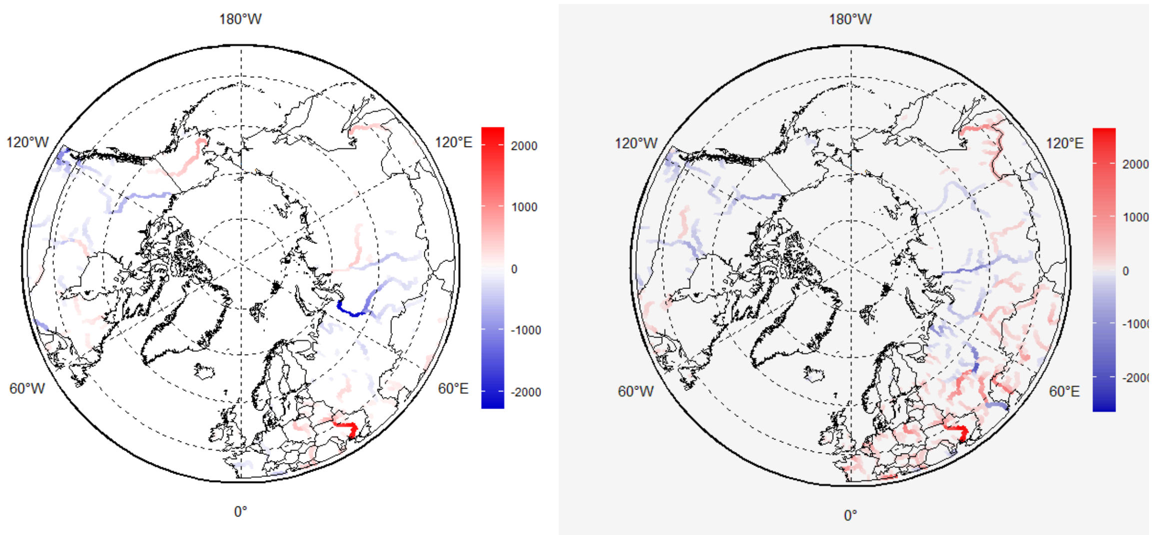


Figure 7: November-January 2023/2024 (left) and February – April 2024 surface precipitation (top) and river discharge (bottom) anomalies (ref. 1991-2020). Maps produced by the AARI. Data source: CCCS ERA5 and RA5-GloFAS.

Verification of winter-spring 2023/2024 forecast

The February – April 2024 precipitation forecast was verified by subjective comparison between the forecast (Figure 8, left) and ERA5 reanalysis (Figure 8, right), region by region. As for temperature, precipitation reanalysis is produced using statistical techniques to fill gaps when meteorological observations are not available.

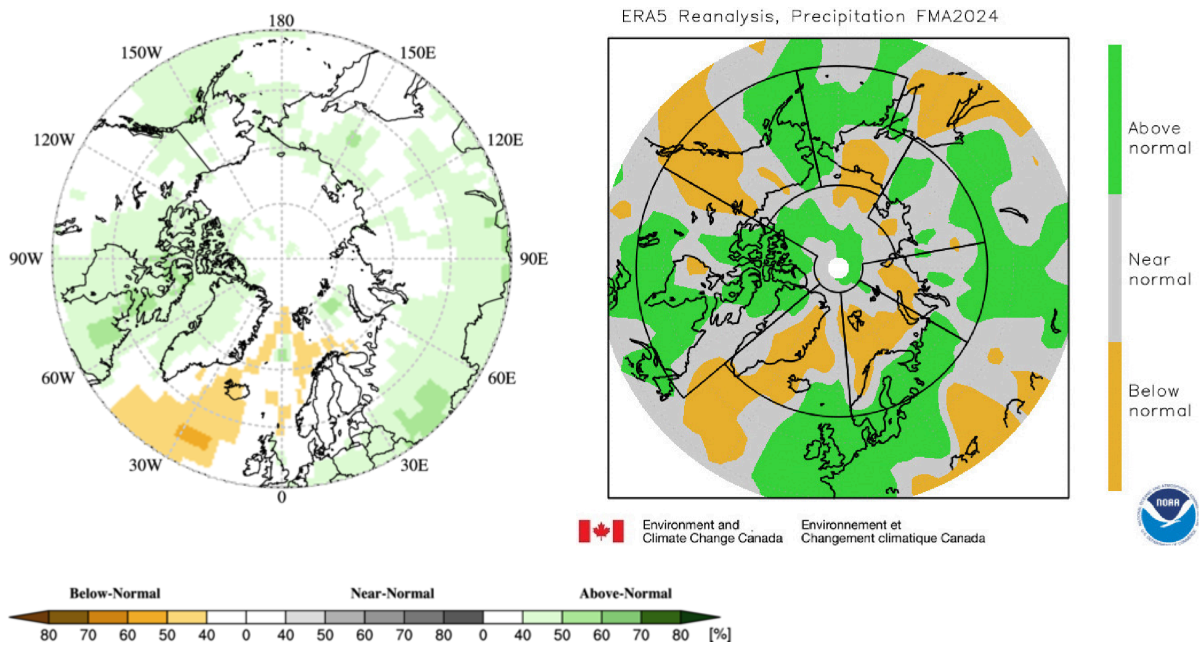


Figure 8: (Left) Multi-model ensemble (MME) probability forecast for precipitation: June, July, and August 2023. Three categories: below normal (brown), near normal (grey), above normal (green); no agreement amongst the models is shown in white. Source: www.wmolc.org. (Right): ERA5 for precipitation for February, March and April 2024.

Overall, the accuracy of the February – April 2024 precipitation forecast was mostly non-decisive above all Arctic regions (Figure 8). In the regions where there was model agreement, the forecast subjective score ranged between 10% to 30%. The forecast captured mostly above normal precipitation over the Central and Eastern Canada region, but missed the near normal precipitation in Alaska and Western Canada and below normal in Chukchi and Bering regions. Overall result, subjective verification for the precipitation forecast is that it was not very performant during the second part of the winter – February – April 2024.

Outlook for summer 2024

For the June – August 2024 period over the largest part of the Arctic region, equal precipitation chances are expected which means that there is no intermodal agreement on the precipitation forecast (Figure 9: white areas; Table 3). Above normal precipitation is expected for marine areas near Iceland, Greenland, the Labrador Sea area, and adjacent parts of Canadian Archipelago, continental parts of Alaska, Chukchi and Kamchatka peninsulas (Figure 9: light green areas; Table 3) with probability expectancies of 40-50%. Minor areas of below normal precipitation are expected for the southern part of Bothnia Bay (Figure 9: light yellow areas; Table 3) with similar probability expectancies of 40-50%.

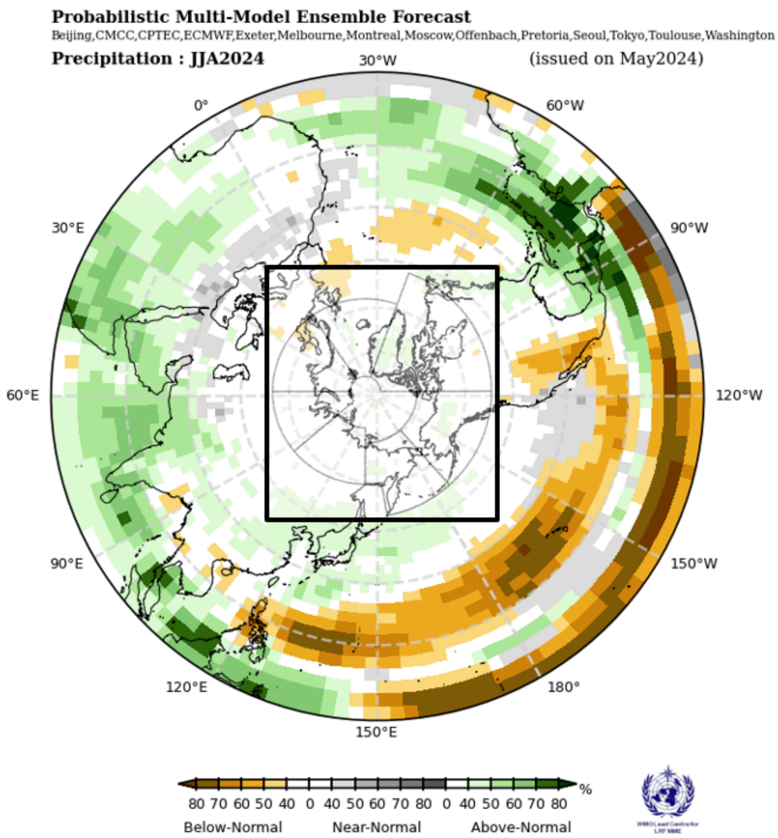


Figure 9: Multi model ensemble probability forecast for precipitation for June, July, August 2024 period. Green indicates probability for wetter conditions, orange indicates probability for drier conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 3. June, July, August 2024 outlook: forecasted Arctic precipitation by region

Region (see Fig.2)	MME Precipitation Forecast Agreement*	MME Precipitation Forecast
Alaska and Western Canada	Low to moderate	Above normal over continental Alaska, no model agreement for other areas
Central and Eastern Canada	Low to moderate	Above normal for Labrador Sea and parts of Canadian Archipelago, no model agreement for other parts

Western Nordic	Moderate to low	Above normal over Greenland, parts of the Greenland Sea and Icelandic waters
Eastern Nordic	Low to moderate	Mostly no model agreement, above normal in the northmost part of Scandinavia, below normal in the southern part of Bothnia Bay
Western Siberia	Low	No model agreement, above normal south of Gulf of Ob
Eastern Siberia	Low	No model agreement
Chukchi and Bering	Low	Above normal in parts of Chukchi and Kamchatka peninsulas, western Aleut islands, southern parts of the Sea of Okhotsk
Central Arctic	Low	Above normal northward of FJL archipelago and North Pole region

*: See non-technical regional summaries for greater detail

Polar Ocean

Summary for winter-spring 2023/2024

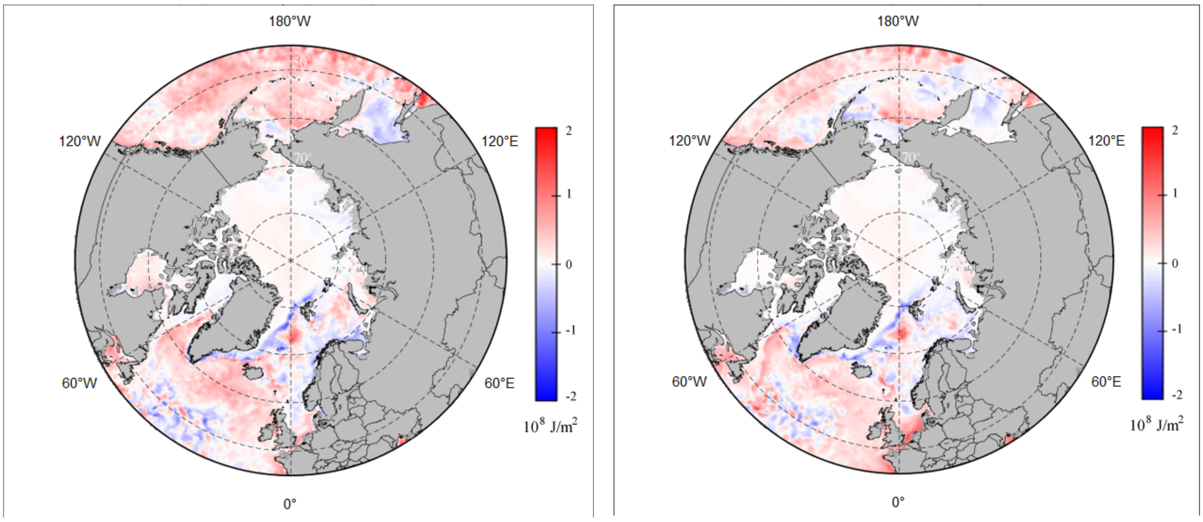
During the first part of the winter 2023/2024 higher 15 m upper ocean layer Heat Content (HC) was noticed in the southern Bering, Northern Barents, southern Greenland waters (figure 11). Lower HC was noticed for northern Bering, Laptev, Okhotsk seas, northern Greenland waters with somewhat neutral over other parts of the Arctic. Later in winter the HC was mostly neutral to 1993-2020 average for most of the Arctic with the same lower exception for the Sea of Okhotsk, Laptev seas, parts of Greenland Sea and higher for southern Bering, Greenland water. In general, the Barents and Bering Seas in 2024 were colder than in 2022-2023.

Numerical models show for the current winter season both positive pH 2m anomalies (alkalization) for the Arctic Basin, Laptev, Chukchi Seas and negative pH anomalies (acidification) for the Barents, parts of the Kara, East Siberian, Greenland Seas to the 1993-2020 period (figure 11), which is in general similar to 2022-2023, the latter may point to alkalization in most of the Arctic Ocean with acidification processes in the Barents, Greenland and Bering Seas though that need verification with ground-truth data.

The negative anomalies point to acidification processes though need further with ground-truth data[2].

[2] Surface sea waters in the Arctic have a pH of about 8.1, with a range of about 7.5 to 8.4. The term ocean acidification refers to an increase in acidity (i.e., a decrease in pH). AMAP, 2019. Arctic Ocean Acidification Assessment 2018: Summary for Policy-Makers. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. 16 p.

15 m upper ocean layer Heat Content



pH 2 meter layer

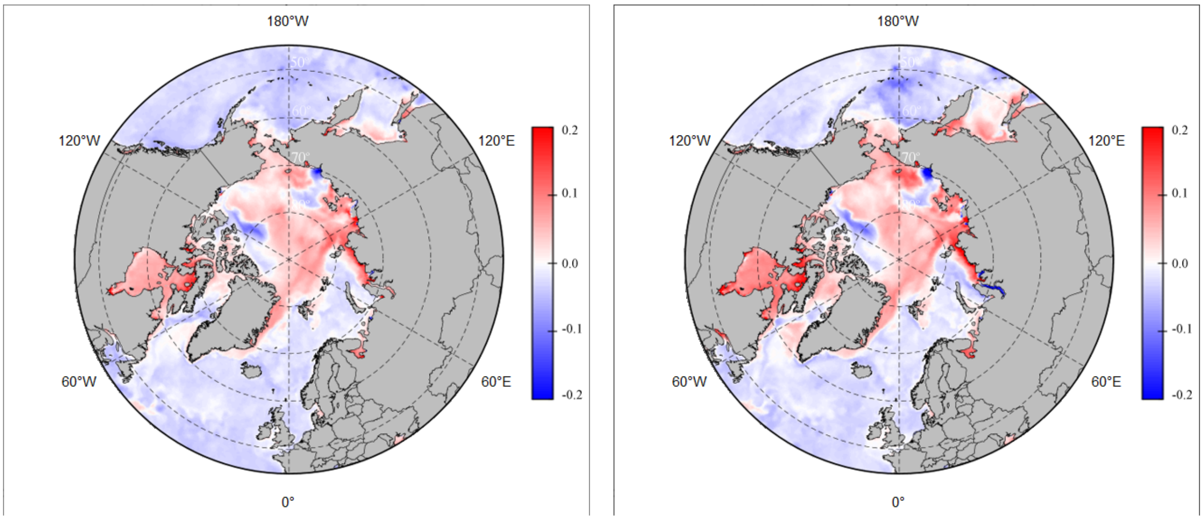


Figure 10: November-January 2023/2024 (left) and February – April 2024 (right) upper 15 m ocean layer heat content (top) and pH 2m ocean layer (bottom) anomaly (ref. 1993-2020 period). Maps produced by the AARI. Data source: CCCS MEMS.

Sea-Ice

Summary for winter-spring 2023/2024

Prevailing positive ocean heat content anomaly during September – November 2023 for the Barents, Kara, parts of Canadian Arctic slowed freezing processes in these regions (see summary for full information). Oppositely, zero or negative HC anomalies in Laptev, ESS, Chukchi, Bering, Okhotsk Seas provided background for closer to normal freeze-up. Further in winter during FMA 2024 occurrence of general positive SAT anomalies over Central Arctic slowed the ice growth, with negative SAT anomalies stimulated ice growth in Eurasian Arctic, Bering and Okhotsk Seas. In addition to SAT, the general ice drift pattern stimulated ice extent in the Barents and Greenland Seas.

Maximum Arctic (Northern Hemisphere) winter ice extent was close to 15th in row (since 1979) and to 15.3 mln km^2 (for 2023 - 7th in row, 14.9 mln km^2) and was reached 12-13 March 2024, which is close in time to climatic date and later by 1 weeks than previous year (figure 12, left). Prominent area of residual ice in late summer led to decadal normal ice extent growth in the Eurasian Arctic. Similar to 2023 the Sea of Okhotsk and the Greenland Sea had ice extent close or higher than 46-years median and the Barents Sea-ice extent close to normal in late winter 2024. Though both winter maximums and summer minimums continue to diminish since late 1990s (figure 12, right) there are some hints in interannual variability pointing to possibility for summer ice cover in 2024 be greater than in 2019-2020 and close to 2021-2023.

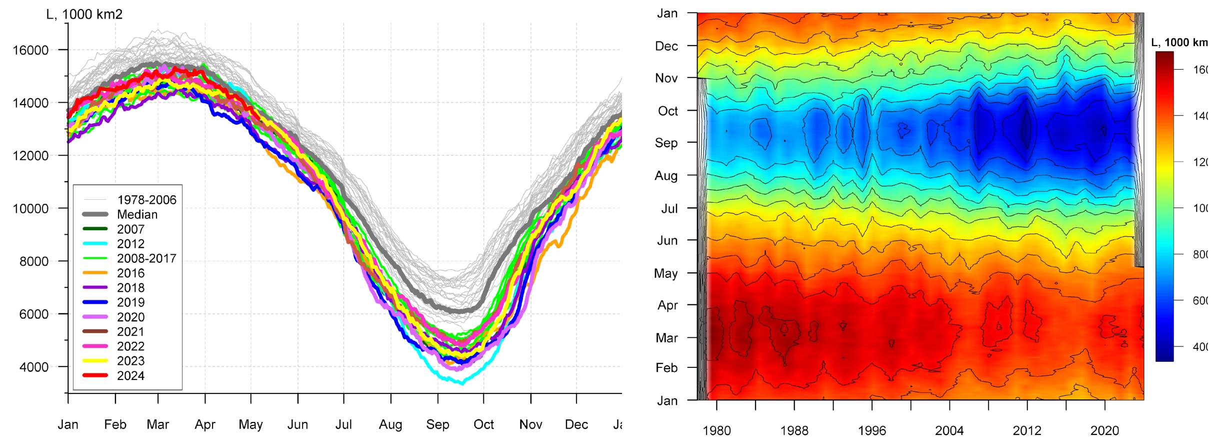


Figure 12: Arctic (Northern Hemisphere) daily annual (left) and daily seasonal (right) ice extent for 1978- 2024. Graphics produced by the AARI. Data source: NSIDC.

Special features of ice conditions in the Arctic during autumn – winter 2023/2024 included (figure 13) occurrence of residual and further in season the second-year ice in the parts of the Laptev and East Siberian Sea and close to normal autumn ice growth within eastern lanes of the NSR, close to decadal normal ice conditions in the Greenland and in late winter in the Barents Sea, close or higher than normal ice conditions in the Sea of Okhotsk which is same as in 2023.

Cryosat-2 measurements in March 2024 (figure 13) show general sea-ice thickness (SIT) growth in the Eurasian Arctic with prominent decline in the Canadian part to average 2011-2024 which explains results of the Arctic sea-ice volume modeling (by the Danish Meteorological Institute, see polarportal.dk) be close to the lowest since 2004 for March 2024.

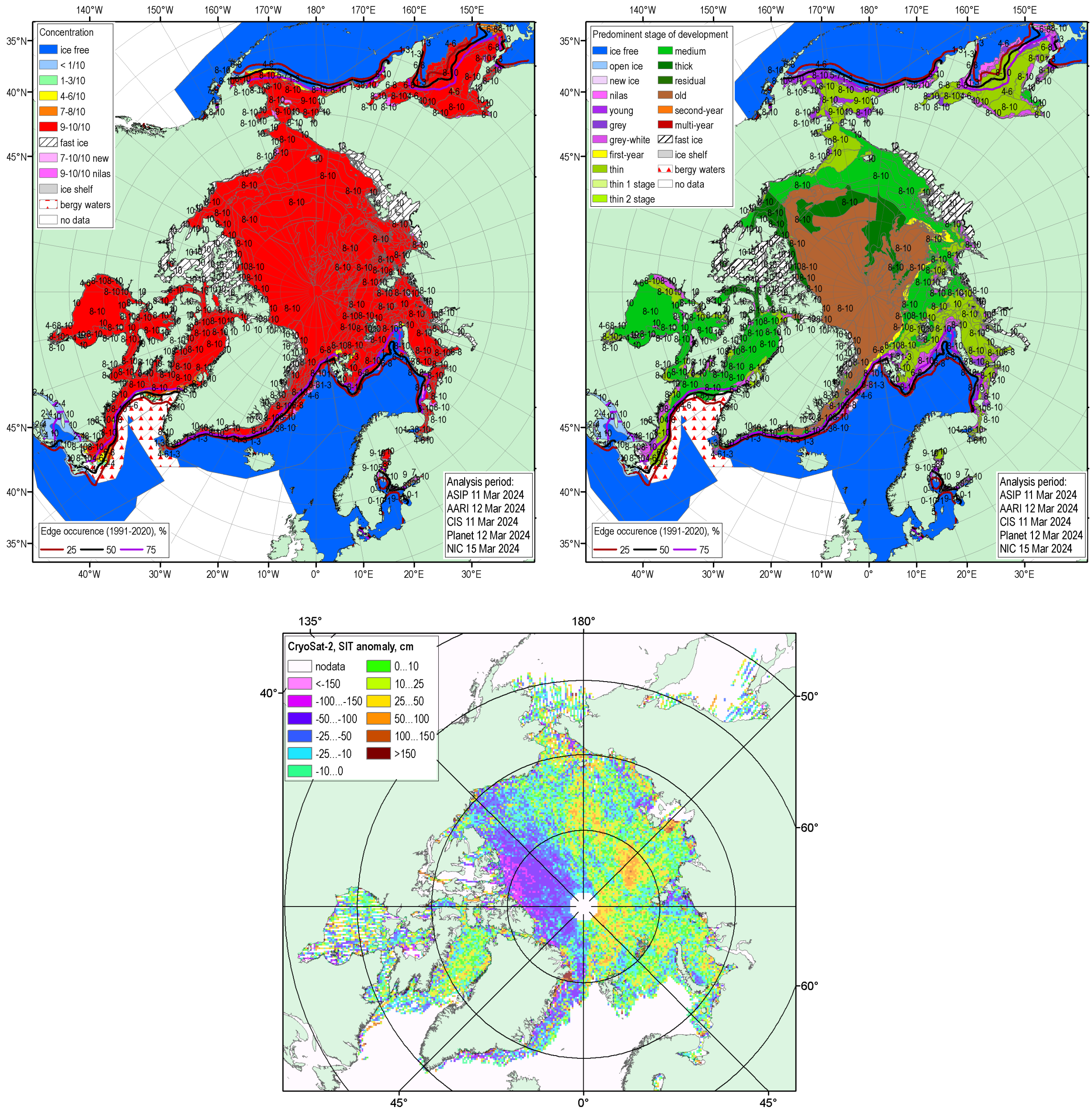


Figure 13: Blended Arctic sea-ice chart (AARI, ASIP, CIS, NIC, Planet) for 11-15 March 2024 and sea-ice edge occurrences for 11-15 March for 1991-2020 reference period (top), left top: total concentration, right top: predominant stage of development.; CryoSAT-2 sea-ice thickness (AWI v2p6) anomaly for March 2024 for 2011-2024 reference period (bottom). Graphics produced by the AARI

Sea-ice Outlook verification for winter 2024 ice extent and freeze-up dates:

The forecast for March 2024 sea-ice extent was primarily based on output from CanSIPS v2.1 (see ArcRCC-N consensus statement for winter 2023/2024). Below normal ice extent was correctly forecasted for the Baffin Bay/Labrador Sea and Gulf of St.Lawrence. Similarly, a correct forecast of above normal extent was predicted for the North Baltic Sea (figure 14). The model did not forecast the above normal ice extent in the Barents, Bering, Greenland, Okhotsk Seas (green areas in figure 14). Forecast accuracy for the winter 2023/2024 freeze-up dates (also based on output from CanSIPS v2.1) was generally good across the Arctic regions. The model correctly forecasted break-up dates in the Hudson and Baffin Bays (where there is a skill), Labrador, Greenland and Beaufort Seas with lower success for Kara and Okhotsk Seas. However, the forecast missed the freeze-up dates anomalies for the Chukchi and Bering Seas where early freeze-up instead of forecasted near normal occurred.

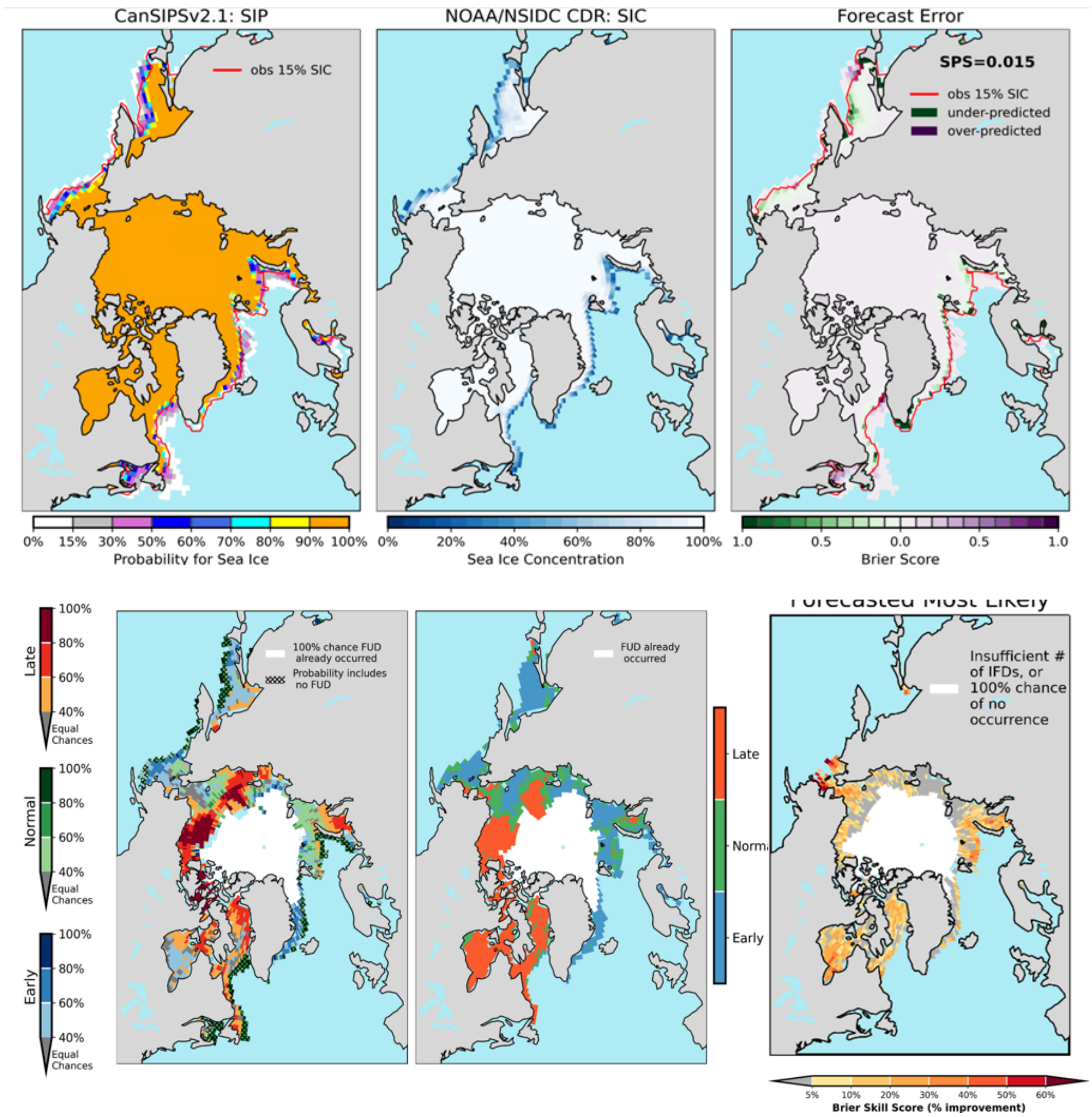


Figure 14: CanSIPS v2.1 probabilistic forecast of March 2024 sea-ice total concentration anomalies (top) and winter 2023/2024 freeze-up dates anomalies (bottom).

Outlook for summer 2024 sea-ice break-up

Sea-ice break-up is defined as the first day in a 10-day interval where ice concentration falls below 50% in a region. The outlook for summer break-up shown in Figure 15 displays the sea-ice freeze-up anomaly in days (deterministic forecast) and the probabilistic forecast from CanSIPSv2.1 based on the nine-year climatological period from 2015-2023. The qualitative 3-category (high, moderate, low) confidence of the forecast is based on the historical model skill. A summary of the forecast for the summer 2024 sea-ice break-up for the different Arctic regions is shown in Table 5.

Earlier than normal freeze-up dates (yellow-red areas, Figure 15; Table 5) are forecasted for parts of the Barents, Kara, East Siberian, Chukchi and Beaufort seas, parts of Baffin and Hudson Bays. A near normal to late break-up (light blue and light-yellow areas, Figure 15, Table 5) is forecasted for parts of Laptev, East Siberian. Late break-up (blue areas, Figure 15,

Table 5) is forecasted for Bering Sea, parts of Chukchi, Labrador, Greenland Seas, west part of Hudson Bay.

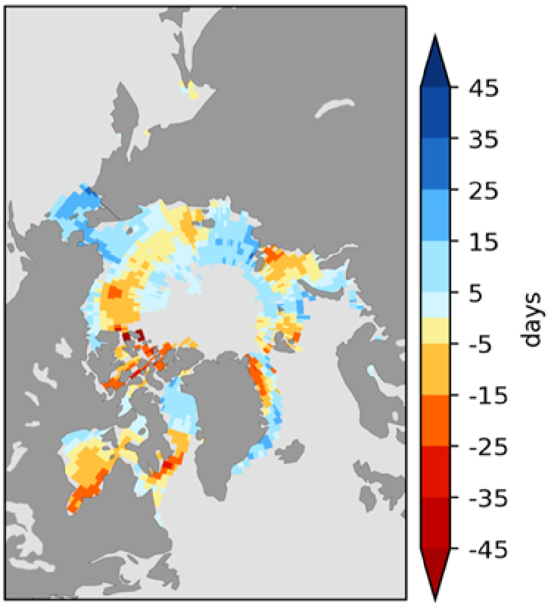


Figure 15: Deterministic break-up forecast from CanSIPSv2.1: break-up date anomaly from 2015-2023 average.

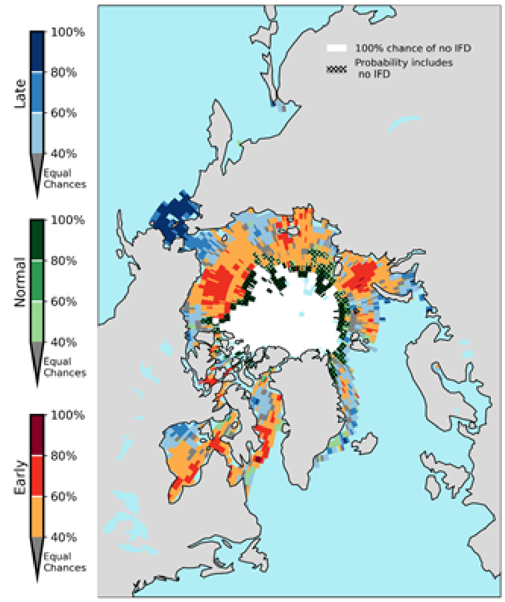


Figure 16: CanSIPS v2.1 Probability for Early, Near-Normal or Late Break-up (forecast from May 1). Note: White area represents 100% chance that retreat does not occur (concentration never <50%). Hatching indicates where near-normal category is most likely, and includes the case that retreat does not occur (concentration never <50%).

Table 5. Summer 2024 outlook: regional forecasts for sea-ice break-up date anomalies

Regions	**CanSIPSv2.1 Sea- Ice Forecast Confidence**	**CanSIPSv2.1 Sea-ice Freeze-up Forecast**
Baffin Bay	High	Early (south), late (north)
Barents Sea	High	Early (west), late (east)
Beaufort Sea	Moderate	Early, late (southeast)
Bering Sea	High	Late
CAA	Low	Late-normal (south), early (north)
Chukchi Sea	Moderate	Late, early (north)
East Siberian	Low	Late (south), early (north)
Greenland Sea	Low	Late-normal (south), early (north)
Hudson Bay	High	Early (east), late (west)
Kara Sea	Moderate	Late (east), early (west)
Labrador Sea	Moderate	Late (west), early (east)
Laptev Sea	No skill	N/A
Sea of Okhotsk	Already occurred	Near normal to early

Outlook for September 2024 Minimum sea-ice extent

Minimum sea-ice extent is reached each year for the Northern Hemisphere polar seas during the month of September with sub-polar seas becoming ice free between June to early August. Table 6 categorizes the sea-ice extent forecast confidence and relative extent (i.e., near normal, below normal, above normal) with respect to a 2015-2023 climatology for the Arctic region. The probabilistic forecast for September 2024 minimum sea-ice extent from CanSIPS v21 is shown in Figure 17; forecast confidence is subjective and based on historical model skill. A below normal September ice extent is forecasted for all regions (Table 6) with exception of below to near normal sea-ice extent for the Barents Sea.

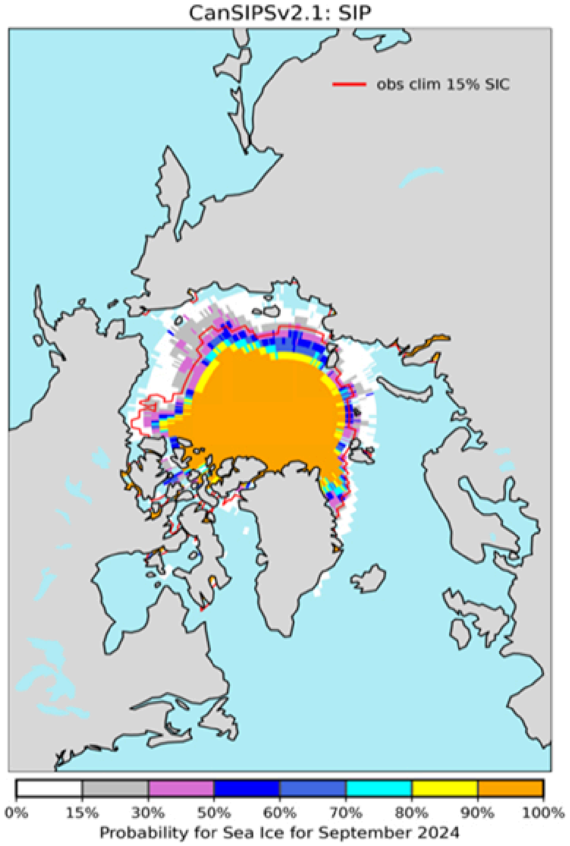


Figure 17: CanSIPSv2.1 September 2024 Sea-ice extent (probability of sea-ice total concentration exceeding 15%).

Table 6. September 2024 outlook: sea-ice extent anomalies by regions

Regions	Sea-ice Forecast Confidence	Sea-ice Forecast Extent
Greenland Sea	Moderate	Below normal
Barents Sea	Moderate	Below to near normal
Kara Sea	Moderate	Below normal
Laptev Sea	Moderate	Below normal
East Siberian Sea	Moderate	Below normal
Chukchi Sea	Moderate	Below normal
Beaufort	Moderate	Below normal

Canadian Arctic Archipelago	Low	Below normal

2024 Summer Ice Conditions in Key Shipping Areas

Northern Sea Route

During the summer of 2024, above-normal temperatures are expected with moderate confidence throughout the Northern Sea Route, except for the Chukchi Sea, where below-normal temperature anomalies are expected. This leads to below-normal sea ice concentrations over most of the Northern Sea Route. However, due to the late break-up of the southern part of the Chukchi Sea and the East Siberian Sea, shipping across the Northern Sea Route is expected to start later than normal. Outlook: later than normal start to the shipping season.

Northwest Passage

Current conditions as of May 20th include earlier than normal clearing for this time of year in M'Clure Strait (northern route) and Amundsen Gulf (southern route) compared to 30-year and 10-year normals with considerably less MYI in the regional compared to 30-year and 10-year normals. Model forecast for an early clearing (low skill) and warmer than normal air temperatures. Outlook: normal shipping season, an early start is likely.

Hudson Bay and Hudson Strait

Current conditions as of May 20th include below normal ice concentrations compared to 30-year normal, below normal ice cover compared to the last 10 years and melt more advanced than at this time last year. Model forecast for earlier than normal break-up, warmer than normal spring temperatures. If the break-up forecast for eastern Hudson Bay is correct, ice could linger by the port of Churchill a little later than normal. Outlook: normal shipping season, an early start is likely.

Baffin Bay

Current conditions as of May 20th include below normal ice concentration compared to 30-year normal, below normal ice cover compared to the last 10 years, less ice cover compared to last year, slightly more old ice in the area compared to 30-year normal, old ice area comparable to last year. Model forecast for an early clearing, warmer than normal air temperatures in southern Baffin Bay but no model agreement in northern Baffin Bay. Outlook: normal shipping season, an early start is likely.

Svalbard area

Early break-up is predicted around Svalbard for the summer 2024. Furthermore, the sea ice extent is predicted to be below normal in September 2024. In Svalbard, a large part of the maritime traffic occurs close to the ice edge for activities like fishing and touristic cruises. Therefore, if the ice edge is located north of the climatological ice edge, this would mean that fishing and touristic cruises will happen at higher latitudes than usual.

Snow Water Equivalent (experimental product)

Outlook for summer 2024

Snow water equivalent (SWE) calibrated probabilistic seasonal forecast for June, July, August 2024 period is performed with Canadian Seasonal to Interannual Prediction System (CanSIPS).

Over the Alaskan and western Canada region there is probability of 40% or more for a below average SWE in the southern parts of the domain (orange and white colors on figure 18) while in the domain's central part the MME is not decisive (white color on figure 18). Over the northern, coastal parts of this domain above normal SWE expectancies are forecasted with at least 50% probability (blue color on figure 10). For most of Central and Eastern Canada below normal SWE is forecasted (orange colors on figure 18) with above normal SWE for the eastmost coastal areas of the region (blue colors on figure 18).

Below normal SWE is expected over Svalbard, Western Siberia and central and southern parts of Chukchi and Bering region with probabilities of at least 60% (red color on figure 10). Coastal area of the Siberian region from the Taymyr peninsula to the Bering Strait should have above normal SWE with 40% probability (blue color on figure 18).

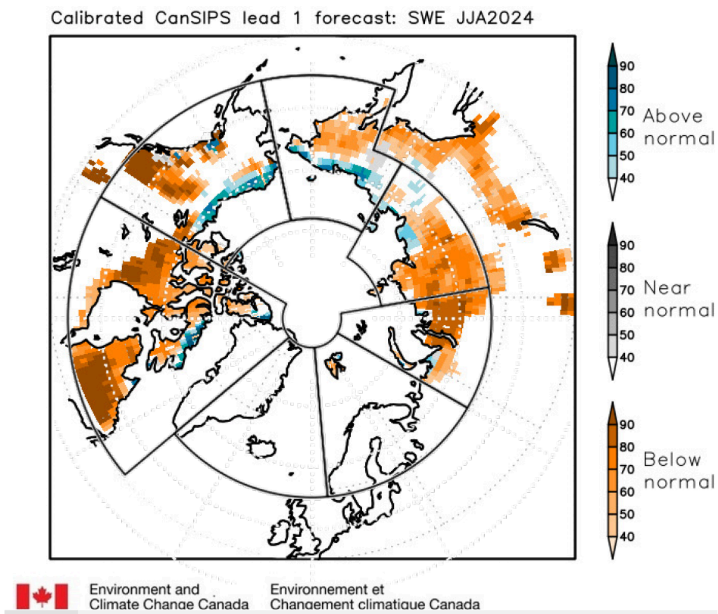


Figure 18: Canadian Seasonal to Interannual Prediction system probability forecast for snow water equivalent for June, July, August 2024 period.

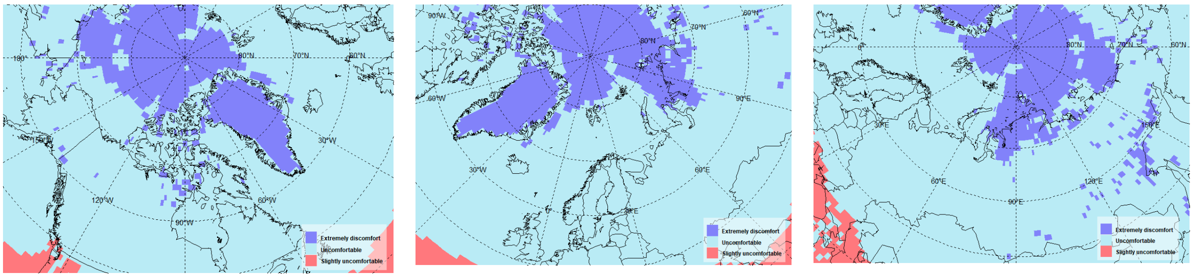
Bioclimatic indexes (experimental product)

Estimates of the weather comfort or bioclimatic indexes are commonly done for the mid-latitude, sub-polar and polar regions using the Bodman's weather severity index (developed specifically for the Arctic cold season, based on a derivative of surface wind speed and air temperature and scaled from slightly severe to extremely severe), or the effective temperature ET (year-round, based on a derivative of surface air temperature and relative humidity and scaled from comfort to extremely discomfort).

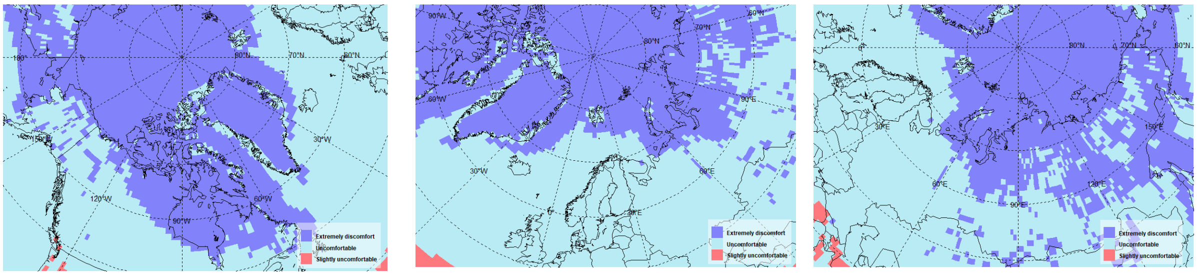
Summary for winter-spring 2023/2024

Extremely severe conditions were observed in October – December 2023 period over the Greenland, in the Central Arctic, over east part of Kara Sea, northern part of Laptev Sea, East Siberian Sea and northern part of Chukchi Sea (figure 19). The Canadian Arctic Archipelago

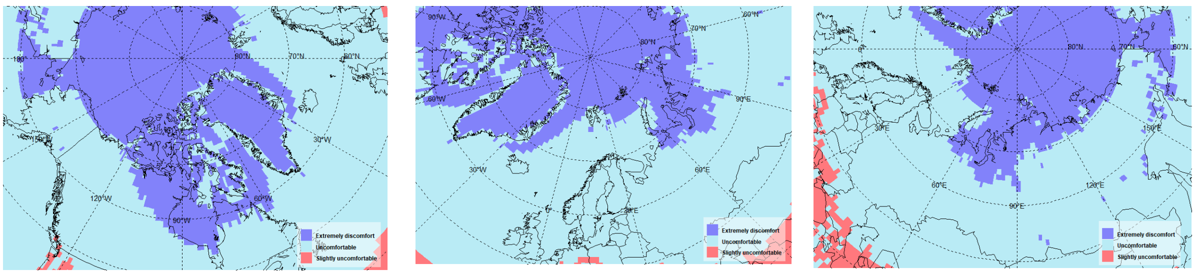
during this period was under severe conditions, while in 2022 all this area belonged to an extremely severe zone. Milder conditions were observed over the North America and adjoined seas, Central Arctic, in Western Siberia, Northern Barents, Kara, Laptev and Chukchi Seas, colder than usual conditions - over western Greenland, Europe, East Siberian Sea, Eastern Siberia and Okhotsk Sea.
Winter period (December 2023 – February 2024) is characterized by an increase of extremely severe zones over Beaufort Sea, the Canadian Arctic Archipelago and land areas south of it, the Hudson and Baffin Bay, the Labrador Sea and the Fram Strait (figure 19). In Eurasian part, extremely severe conditions widened over all seas of the Northern Sea route, including eastern and northern parts of Barents Sea, over land in the Western and Eastern Siberia (with some gaps), Bering and Okhotsk Seas. This winter proceeded with milder conditions in North America and Central Arctic, also milder or close to normal conditions were over Central Europe. Colder conditions were observed over Scandinavia, European part of Russia, Ural, east of Eastern Siberia, Alaska and Aleutian Islands.



October-December 2023



December 2023 – February 2024



February - April 2024

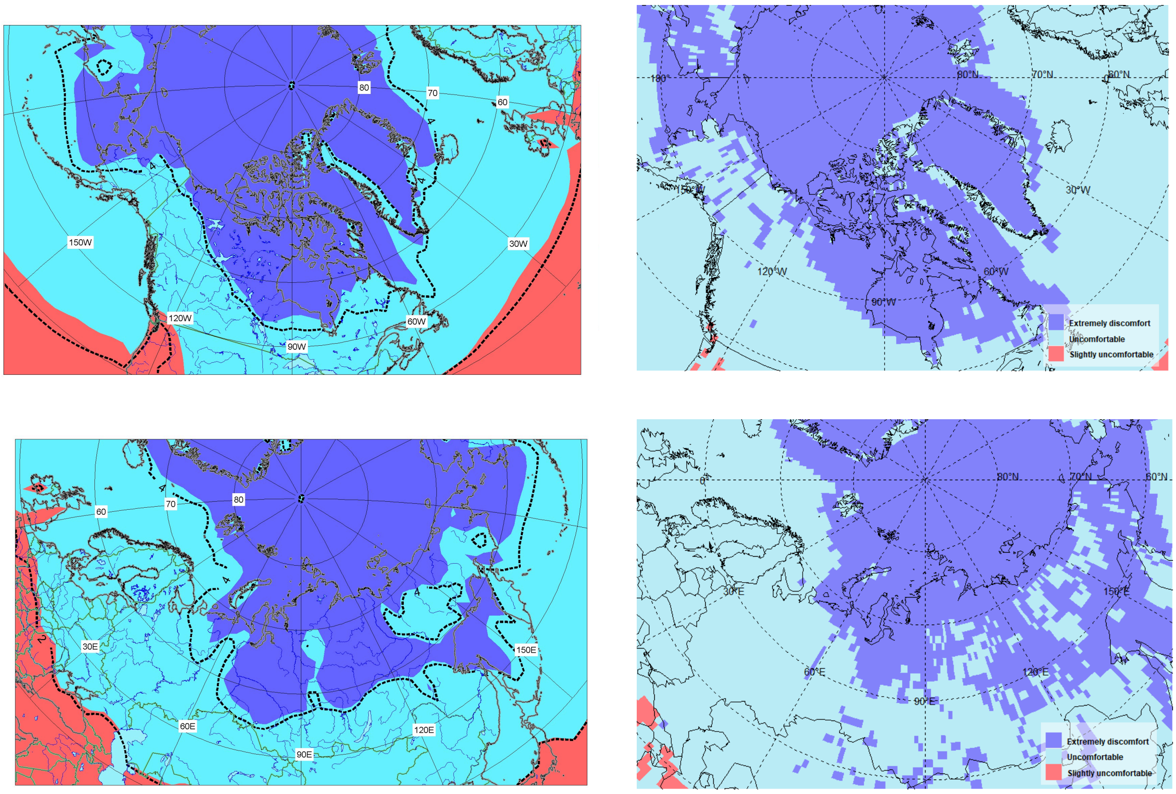
Figure 19: Bodman's index (S) of weather severity for October 2023 – April 2024. Maps produced by the AARI. Data source: CCCS ERA5.

In February – April 2024, extremely severe conditions were decreased over eastern Canada, Labrador Sea, Okhotsk Sea, eastern Barents Sea and around Svalbard (figure 19). In the inland parts of Siberia extremely severe conditions remained only over the shores and in Gulfs of Ob' and Yenisei, over the Taymyr Peninsula. The predominance of milder conditions was observed in FMA period, but there were as well areas with colder conditions: Western

Siberia, especially Gulfs of Ob’ and Yenisei, area to the north from Bering Strait, Koryak Highlands and area of Aleutian Islands, south of Alaska Peninsula, shore of eastern Greenland. The situation in the central Arctic and especially in the North European basin differs greatly from 2023, when there were rather cold conditions in winter and spring periods.

Verification of winter-spring 2023/2024 forecast

For the Alaska and Canada region the forecast identified extremely severe conditions quite accurate (figure 20), it only underestimated the situation over the southern part of Labrador Sea and Labrador province (there were extremely severe conditions according to ERA5 rather than severe conditions in forecast). The Eurasia region forecast was also quite accurate, except for some land areas in the far east of Eastern Siberia and adjacent western part of Bering Sea, where the severity was underestimated (there were extremely severe conditions according to ERA5 rather than severe conditions in forecast).



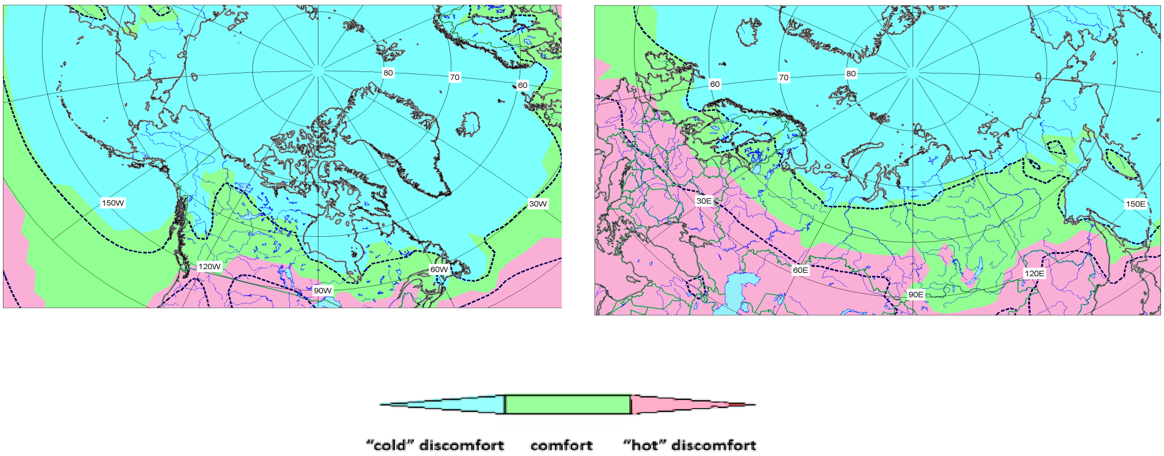
Forecast ERA5 data

Figure 20: Bodman’s index (S) of weather severity forecast (left) and ERA5 reanalysis estimate (right) for December 2023 – February 2024. Maps produced by the AARI and Hydrometcenter Russia. Data source: Hydrometcenter Russia and CCCS ERA5.

Outlook for summer 2024 (experimental)

Forecast of the bioclimatic indexes for summer 2024 (June, July, August 2024) is provided in the form of effective temperature and is based on the operational subseasonal/seasonal forecasts from the collaborative model of the Institute of Numerical Mathematics RAS and Hydrometcentre of Russia and corresponding hindcasts for 1991-2020 to calculate the norms. In the Western Hemisphere in the summer of 2024 (figure 21, table 7) cold discomfort conditions are expected in Alaska, in the western Yukon, in the north of the Northwest Territories, Nunavut and Quebec, in Greenland, comfortable conditions – in the center and south of the Northwest Territories, in the south of Nunavut and Quebec with no hot discomfort conditions expected in Arctic Zone.

Alaska, Canada and Western Nordic **Eurasia**



-------- norm (1991-2020)

Figure 21: Effective temperature for June, July, August 2024. Maps and data source: Institute of Numerical Mathematics Russian Academy of Science.

Table 7: Regional comparison of Bodman's weather severity index for summer 2024

Regions	Summer	June	July	August
Alaska and Western Canada				
Central and Eastern Canada				
Western Nordic				
Eastern Nordic				
Western Siberia				
Eastern Siberia				
Chukchi and Bering				

Less comfortable than 1991-2020	More comfortable than 1991-2020

Regions	Summer	June	July	August
Alaska and Western Canada				
Central and Eastern Canada				
Western Nordic				
Eastern Nordic				
Western Siberia			!	
Eastern Siberia			!	
Chukchi and Bering				

In the Eastern Hemisphere in the summer of 2024 (figure 21, table 7) cold discomfort conditions are expected in Iceland, most of Norway and Sweden, in the north of Finland (this is consistent with long-term averages 1991-2020). On most of the Arctic coast of Russia, bioclimatic conditions will be also relatively cold and uncomfortable in general, but the comfort zone will shift slightly northward relative to the norm in Western Siberia, Eastern Siberia and Chukotka.

In the summer 2024 (table 7) weather conditions are expected to be more comfortable than normal everywhere, with the exception of the Western Nordic. It will be less comfortable in June in the Western Nordic and Chukchi Bering Nodes. in July in the Western and Eastern Siberia nodes it is expected not just more comfortable weather, but a transition in the gradation of heat sensation from discomfort to comfort.

Observed extreme events

Category	Location	Rarity	Impacts associated with event
		Alaska and Western Canada	
Precipitation and temperature (winter)	Alaska	2nd snowiest January on record at the Juneau Intl Airport followed by melt. Nov-Dec: extreme snowfall Anchorage area (Highest Nov-Dec amount on record).	Record snowfall in a two-week period in Juneau followed by a rapid warm-up and rainfall caused local flooding issues. Weeks-long travel hazard in the Anchorage area from heavy snowfall and numerous structure collapses due to heavy snow load.
Temperature (spring)	Alaska	April: Extreme cold during the first week of April.	Delayed snow melt-off. Concern regarding the late-month breakup did not materialize.
Precipitation (winter)	Yukon	Unusually thin ice on the Yukon River at Dawson City.	The government-sponsored ice bridge across the Yukon River at Dawson City was not built this year due to warm temperatures and thin ice.
Precipitation (spring)	Alaska	March-April: Very heavy snow along most of the Alaska west coast. High season SWE.	Travel impacts. Subsistence impacts
Flooding	Alaska and Yukon	April-May: early river breakup at most locations. Flooding significant in a few areas. Not as bad as last year.	Road damage and severe erosion along the lower Kuskokwim River.
		Central and Eastern Canada	
Temperature (winter)	ISR and Nunavut Nunavik Nunatsiavut	Arviat, Cambridge Bay, Rankin Inlet ranked 1st warmest winter on record In mid-January, the region experienced well above normal temperatures, at times 15°C above normal Makkovik ranked 2nd warmest winter on record, Nain ranked 3rd warmest winter on record	December: dangerous subsistence fishing and traveling on the ice – increase in number of people falling through the ice In mid-January, precipitation fell as rainfall over Baffin Island due to unusually warm temperatures. Major water pooling issues as well as significant ice after refreezing. Iqaluit city shut down due to unsafe icy conditions. Jan 6, 2011 was the last January rain in Iqaluit
Precipitation (winter)	ISR and Nunatsiavut	Inuvik ranked 1st wettest December on record Makkovik received 150 cm of snow over a single week, more than twice the normal amounts for February	Aklavik-Inuvik winter road opening was delayed due to heavy snowfall. For the first time since 2006, the road opened in January, when it usually opens before Christmas Day. In February, the highway was closed for an extended period of time due to successive snowfall events followed by strong winds blowing in the exceptionally high snow bank, creating a concern over available critical supply resources
Blizzards/Wind	Nunavut	Early season blizzard (>48 hrs) with record setting wind gusts in many communities Strongest wind gust on record – Kugaaruk(100 km/h) Strongest sustained winds and/or gusts on record for the month of November: 100-126 km/h and 27 hours with wind gusts exceeding 100 km/h	Infrastructure damage due to strong winds, prolonged power outages (> 4 days), 1 death, local state of emergency declared

Sea-ice	Nunatsiavut	Freeze-up nearly 4weeks behind normal by mid-January	
Western Nordic			
Precipitation (winter DJF)	Greenland, North	Unusually wet winter in North Greenland. The wettest on record at Station Nord since the beginning of measurements 1961. January and February were especially wet.	
Sunshine, Drought	Iceland, Southwest	Winter (NDJFMA). Sunniest winter in Reykjavík since the beginning of measurements (1911). Among the drier winters in the area	None
Eastern Nordic			
Weather (storm Ingunn, 3 intense storms)	Northern Norway	Very rare during such a short time span	Several thousand people without electricity, Disrupted flight traffic Bridge closed in Tromsø
Weather	Saami communities in Northern Norway, Sweden and Finland	First part of winter: Very cold, with early snow but strong variations between areas	In areas without snow the early cold was good for the reindeer grazing conditions In areas with much early snow there were challenges for transport since open water did not yet freeze enough Early freeze-up of rivers with decreasing water levels created risk of reindeer falling
Weather	Saami communities in Northern Norway, Sweden and Finland	Second part of winter: High variability in weather conditions with mild & rainy periods, as well as cold spells	Rain on snow creates ironcrust, which led to difficult grazing and more walking of reindeer to find good pastures Strong winds and mild weather may have improved pastures in some areas temporarily
Sea-ice	Lot of sea-ice in Isfjorden (Longyearbyen)	Rare in the last few years	
Western Siberia			
Weather	Yamal-Nenets Autonomous District	Ones every 5-6 years	Warm February, despite the lack of precipitation, caused thaws and precipitation in the form of sleet. Thaws were recorded at 50% of stations in the Yamalo-Nenets District. After the thaw, an ice crust formed on the snow (in some areas up to 13 cm thick), which, due to the cold weather in the spring, did not melt until April. According to the Agricultural Bulletin, problems with obtaining food in reindeer pastures were observed from February to April 2024. Private farms are reporting large losses in their herds.
Eastern Siberia			
Cold wave	Northeastern part of Sakha republic 15-21 February	In mid-February for the first time in 30 years	New daily air temperature records (-50..-52°C) have been set. Schools have been switched to distance learning. Cases of frostbite among the local population and electrical accidents were reported.
Chukchi and Bering			

Precipitation	Northern Chukchi peninsula and adjacent area of the Sakha Republic	Interannual variability	The frequent recurrence of snowfalls in the winter months has led to significant positive snow cover anomalies. Large-scale floods are expected during the beginning of summer 2024 on the Kolyma and Yana rivers (dangerous water levels have already been recorded on these rivers upstream). In the village of Zyryanka the airport (runway) was flooded.

Possible impacts for summer 2024

Economy sector/ Livelihood conditions	**Outlook**	**Impacts associated**	**Ongoing Impacts of Climate Change**
Alaska and Western Canada			
Harvesting Activities on the land and sea-ice	Delayed start to wildfire season eastern Alaska/NW Canada High early summer rivers levels Alaska/Yukon	Possible cash income loss Higher risk increased river erosion Lower risk of shipping delays for	Increase risk of coastal flooding and thawing permafrost coastal erosion and community infrastructure All marine mammals with habitat on sea ice may be more difficult to harvest
Bering Sea Fisheries	Late (but patchy) sea ice melt and resulting cool sea surface temperatures at least through early summer	Potential for more historically usual ocean ecosystem patterns	
Central and Eastern Canada			
Subsistence fishing and hunting	Below normal ice, above normal temperatures	Unsafe subsistence fishing	Increasing interannual and intraseasonal variability lowers predictability of weather extremes
Sea Lift, Resupply, MDA	Below normal ice, above normal temperatures		
Tourism	Below normal ice, above normal temperatures	Increasing tourism in the north, particularly adventure travelers through the NWP	
Western Nordic			
Land and marine activities	Temperature and precipitation near normal	No special impacts are anticipated	Increasing interannual and intraseasonal variability lowers predictability of weather extremes
Western Siberia			
Livestock farming	Above norm T2m and Prec on the east	In the east of the Yamalo-Nenets Okrug, warm conditions can cause heat waves, warm and humid weather causes muggy weather with a lot of insects, which is unfavorable for local and domestic animals.	Increasing interannual and intraseasonal variability lowers predictability of weather extremes

Eastern Siberia			
Forestry	Above norm air temperature	An increased risk of wildfires is expected due to above-normal temperatures forecast for northern Eastern Siberia.	Increased interannual and intraseasonal variability lowers predictability of weather extremes
Health/Wildlife	Above norm air temperature	Heat waves	
Hydrology	Uncertainty in precipitation	Small snow reserves may affect the flood season on of main Arctic rivers (Lena, Yana, Indigirka), if there is uncertainty in precipitation - a small risk can be assumed	
Chukchi and Bering			
Shipping/transport	Late break-up of Bering Sea and south of Chukchi sea	Shipping across the Northern Sea Route is expected to be start later than normal	Increased interannual and intraseasonal variability lowers predictability of weather extremes
Transport and livelihood	Floods	Due to warm weather and high snow cover (by May 20 in Chukotka the snow height reached 20-30 cm), heavy floods are expected on the northern rivers in early June	

Data sources and useful links:

Arctic and Antarctic Research Institute

- Seasonal bulletins of the state of Arctic (in Russian)
- Seasonal NSR outlooks (in Russian)
- ArcRCC-N NE node monthly and seasonal graphs for the Arctic ECVs
- ArcRCC-N NE node Arctic Ocean blended ice charts

Copernicus Climate Change Service

- ERA5 monthly averaged data on pressure and single levels (ERA5)
- Marine environment monitoring service (CMEMS)
- GloFAS operational global river discharge reanalysis (ERA5-GloFAS)

Danish Meteorological Institute

- Polar Portal
- Ocean and sea ice services

Finnish Meteorological Institute

Environment Canada and Climate Change

- Seasonal forecasts
- Canadian Ice Service latest ice conditions and forecasts

ESA CryoSAT-2 sea-ice thickness estimates (AWI)

Icelandic Meteorological Office

National Snow and Ice Data Center (NSIDC)

- NSIDC Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea-ice Concentrations

NOAA/National Weather Service Alaska Forecast Office

- NWS Alaska Sea Ice Program

Norwegian Meteorological Institute

Swedish Meteorological and Hydrological Institute

US National Ice Center

WMO Arctic Regional Climate Centre - Network (ArcRCC-N)

WMO Global Cryosphere Watch (GCW)

- GCW SnowWatch
- Rutgers Univercity Global Snow Lab

WMO Lead Center for Long-Range Forecast Multi-Model Ensemble

- Seasonal forecast

Background and Contributing institutions

The Arctic seasonal climate summary and outlooks were prepared for ACF-13 in partnership between the Canadian, Danish, Finnish, Icelandic, Norwegian, Russian, Swedish and United States meteorological agencies, sea-ice services and with contributions from the WMO GCW. The ArcRCC-Network, a collaborative arrangement with formal participation by all the eight Arctic Council member countries, is designated as a WMO RCC-Network by the WMO Executive Council in June 2024. For more information, please visit https://arctic-rcc.org/.

Acronyms

AARI	Arctic and Antarctic Research Institute
ArcRCC-Network	Arctic Regional Climate Centre Network (https://www.arctic-rcc.org)
ACF	Arctic Climate Forum
AMAP	Arctic Monitoring and Assessment Programme
CAA	Canadian Arctic Archipelago
CanSIPSv2	Canadian Seasonal to Inter-annual Prediction System
CAP	Common Alerting Protocol
CCCS	Copernicus climate change service
CIS	Canadian Ice Service
CMEMS	CCCS Marine environment monitoring service
DMI	Danish Meteorological Institute
ECCC	Environment and Climate Change Canada
ECMWF	European Centre for Medium-Range Weather Forecasts
ESA	European Space Agency
FMI	Finnish Meteorological Institute
GCW	Global Cryosphere Watch
GPCs-LRF	WMO Global Producing Centres Long-Range Forecasts
GloFAS-ERA5	CCCS operational global river discharge reanalysis
GloSea5	Met Office Global Seasonal forecasting system version 5
H50, H500	Geopotential heights 50hPa, 500hPa
HYCOM-CICE	HYbrid Coordinate Ocean Model, Coupled with sea-ice
IICWG	International Ice Charting Working Group
IMO	Icelandic Meteorological Office
IOC	Intergovernmental Oceanographic Commission
LC-LRFMME	WMO Lead Centre for Long Range Forecast Multi-Model Ensemble
MSLP	Mean sea level pressure
NAO	North Atlantic Oscillation
NIC	National Ice Center (United States)
NCAR	National Center for Atmospheric Research
NCAR CFSR	National Center for Atmospheric Research Climate Forecast System Reanalysis
NMI	Norwegian Meteorological Institute
NOAA/NWS/NCEP/CPC	National Oceanic and Atmospheric Administration/National Weather Service/National Centers for Environmental Prediction/Climate Prediction Center (United States)
NSIDC	National Snow and Ice Data Center (United States)
MME	Multi-model ensemble
NSR	Northern Sea Route
NWP	Northwest Passage
PIOMAS	Pan-Arctic Ice Ocean Modeling and Assimilation System
RCC	WMO Regional Climate Centre
RCOF	Regional Climate Outlook Forum
SAT	Surface air temperature
SST	Sea surface temperature
SMHI	Swedish Meteorological and Hydrological Institute
SWE	Snow Water Equivalent
WMO	World Meteorological Organization